# Interference Management in Heterogeneous Network With Particle Swarm Optimization

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***Abstract*—In heterogeneous network, femtocell is deployed inside macrocell coverage. Femtocell and macrocell use the same frequency as the resource. Thus, if the resources are not properly allocated, the interference will arise. The higher level of interference results in decreasing signal quality. Therefore, interference management is needed to increase network capacity and system performance. This research implements particle swarm optimization (PSO) algorithm to minimize interference on the heterogeneous network. Based on the simulation results, it is shown that PSO algorithm works efficiently to increase the throughput value of femto user equipment (femto UE) up to 62,2 Mbps by minimizing the interference.**

***Keywords*—*interference, heterogeneous network, PSO***

## I. Introduction

Femtocell is a low-power micro transmitter technology, also called HeNB, with its ability to increase capacity and expand the macrocell coverage. Femtocell has been used in various wireless communication standards [1]. Femtocell is built inside macrocell networks. Macrocell networks provide wider signal coverage compared to femtocell. Under these conditions, a heterogeneous network is formed [2], as shown in Fig 1. The sharing frequency method is used in this heterogeneous network. It means femtocell and macrocell network use the same frequency allocation.

However, if the frequency resource is not properly allocated, then the system performance will decrease due to interference [3]: co-tier interference from a neighbor femto BS and cross-tier interference from a macro BS. Signal quality will decrease as a result of higher levels of interference. Therefore, interference management is needed to increase network capacity and system performance. The interference can be minimalized by allocating the reosurce properly.

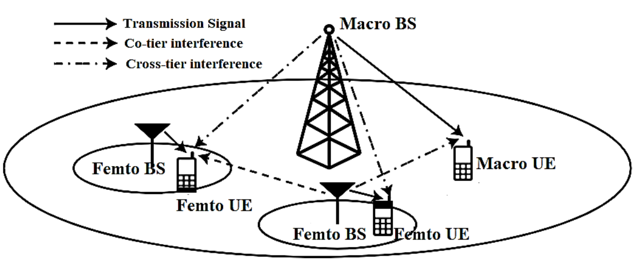


Fig 1. Interference scheme in femto-macrocell network.

Nature-inspired metaheuristic algorithm is an excellent method that can be used to solve the resource allocation problem. In nature-inspired metaheuristic algorithm, each algorithm is inspired by the behavior of living things [4],[5] such as birds, fish, ants, bacteria, and bat. In [6]-[7], genetic algorithm is used for interference mitigation by maximize the total achievable throughput. Ant colony optimization are considered in [8] for sub-channel allocation. The objective function in the research is to maximize the total rate sum of multiple femto user equipments (femto UEs). In [9] and [10], particle swarm optimization is used to maximize the minimum of throughput network.

The objective of this research is to develop resource block allocation for interference mitigation in femtocell based on particle swarm optimization.

## II. Study Literature

### *A. Femtocell*

Mobile users in indoor environment usually experience a signal quality degradation due to wall penetration loss by ceiling or floors between the base station transceiver (BTS) and the mobile user equipment. This quality degradation leads to the lower throughput. Thus, femtocell is considered to tackle this problem.

The term of "femto" in femtocell means $10^{-15}$, which means the equipment dimension is much smaller than the standard macrocell cellular towers. Higher received signal strength and saver phone battery can be achieved by the user due to the distance reduction between the femtocell and the user. Moreover, mobile operator also took some advantages such as cost reduction of the deployment macrocell network and increasing the network capacity.

### *B. Particle Swarm Organization (PSO)*

Particle swarm optimization is a well-known population-based metaheuristic algorithm inspired by the social behavior of particle such as birds or fish movement. The position and velocity of each particle are the main parameter in this algorithm. Each particle changes their position around the multidimensional search space and adjusts its position based on its personal experience and its neighbor particle.

PSO method combine local search method with global search method [11]. The initialization of the PSO algorithm starts by randomly assigning the initial position of the particle and then calculate the fitness value by objective function. Each particle in each iteration updates its position towards the two best values: *Pbest* and *Gbest*. *Pbest* is the best solution that has been obtained by each particle and *Gbest* is best solution of the population. After obtained *Pbest* and *Gbest* in the initialization process, the position and velocity at each particle is updated based on equation below

$$v_i^k = wv_i^k + c_1 r_1 (pbest_i^k - x_i^k) + c_2 r_2 (gbest_i^k - x_i^k) \quad (1)$$

$$x_i^{k+1} = x_i^k + v_i^{k+1} \quad (2)$$

where $v_i^k$ is the velocity of the *i*-th particle at *k*-th iteration, and $x_i^k$ is solution (position) of *i*-th particle at *k*-th iteration. $r_1$ and $r_2$ variable are two random variable which produce random number between 0 and 1. In PSO, there are learning factor $c_1$ and $c_2$. The iteration will be continued after the termination criteria is fullfiled, such as number of generation or toleration value. In the end, the best solution, $G_{best}$, is obtained.

## III. System Model

### A. Network Topology

In this research the system model is designed based on standard simulation of LTE 3GPP downlink communication for macro-femto networks with closed access types, as shown in Table 1. Femtocell is deployed inside macrocell network and is located in the apartment block. Each apartment block is assumed as a grid model 5 x 5 meters.

Table 1. System Parameters and Values

| No | Parameters | Values |
|---|---|---|
| 1 | Macrocell layout | Grid Hexagonal |
| 2 | Femtocell layout | Grid model 5x5 |
| 3 | Macro/Femtocell radius | M = 500 m, F = 5m |
| 4 | Number of MUE | 5 MUE/sector, 1 HUE/Femto BS |
| 5 | Number of apartment block | 4 apartment / sector |
| 8 | Shadowing standard deviation | 8 dB (outdoor), 10 dB (indoor) |
| 9 | Wall loss penetration | 20 dB |
| 10 | Macro BS antenna | $A_H(\theta) = -\min\left[12\left(\frac{\theta}{\theta_{3dB}}\right)^2, A_m\right]$ $\theta_{3dB} = 70$ and $A_m$ = 20 dB |
| 11 | Femto BS antenna | Omnidirectional |
| 12 | Antenna gain BS | 14 dBi (makro BS), 0 dBi (Femto BS) |
| 13 | Antenna gain UE | 0 dBi (MUE), 0 dBi (FUE) |
| 14 | Traffic model | Full buffer |

Each element in this network, except the macro BS, is randomly deployed. In this research, only the interference in femtocell network is taken into account. After the network is deployed, the path-loss is calculated based on Eq. (3)-(5).

- Pathloss from Femto BS to Femto UE :

$$P_{L(same\ block)}(dB) = 127 + 30\log_{10}(d[km]) + X_{\sigma m} \quad (3)$$

$$P_{L(different\ block)}(dB) = 127 + 30\log_{10}(d[km]) + L_W + X_{\sigma m} \quad (4)$$

- Pathloss from Macro BS to Femto UE :

$$P_L(dB) = 128.1 + 37.6\log_{10}(d[km]) + X_\sigma + L_W \quad (5)$$

where *d* means the distance between base station and user equipment. Wall loss penetration and shadowing effect are denoted as $L_w$ and $X_\sigma$, respectively.

### B. PSO Application in Interference Management

In PSO application, the position of each particle is defined as a femto BS who find the target. In order to minimize the interference, a femto BS must 'find' the most appropriate resource block, which analogous as the target, for femto UE *u*. Each particle poisition is recorded in a $1 \times H$ matrix as described below

$$X_i^t = \begin{bmatrix} \overline{x_1} \\ \overline{x_2} \\ \vdots \\ \overline{x_u} \end{bmatrix}$$

$$X_i^t = \begin{bmatrix} c_1^{(1)} & c_1^{(2)} & \cdots & c_1^{(H)} \\ c_2^{(2)} & c_2^{(2)} & \cdots & c_2^{(H)} \\ \vdots & \vdots & \cdots & \vdots \\ c_u^{(1)} & c_u^{(2)} & \cdots & c_u^{(H)} \end{bmatrix}$$

where $\overline{x_u}$ symbolizes the subsets of allocated resource block $c_u^{(H)}$ in each femto UE. Each particle velocity is also recorded in a matrix, called velocity matrix $V_i^t$ as shown below

$$V_i^t = \begin{bmatrix} \overline{v_1} \\ \overline{v_2} \\ \vdots \\ \overline{v_u} \end{bmatrix}$$

$$v_i^t = \begin{bmatrix} v_1^{(1)} & v_1^{(2)} & \cdots & v_1^{(H)} \\ v_2^{(2)} & v_2^{(2)} & \cdots & v_2^{(H)} \\ \vdots & \vdots & \cdots & \vdots \\ v_u^{(1)} & v_u^{(2)} & \cdots & v_u^{(H)} \end{bmatrix}$$

When each particle gets closer to the target, update position and velocity using the Eq. (1) and Eq. (2), respectively. Next, calculate SINR for each user based on the objective function below

$$SINR_{u,c} = \frac{P_{u,c}^f . g_{u,c}^f}{\sum_{u'=1,u'\neq n}^{N} P_{u',c}^{f'} . g_{u',c}^f + P_{o,c}^m . g_{o,c} + N_O . B_O} \quad (6)$$

where $P_{u,c}^f$ is a power gain of the user *u* serve by the femto BS *f*, while $P_{u',c}^{f'}$ and $P_{o,c}^m$ is the power gain of the user *u* to the Femto BS interferer and the interferer Macro BS in each sub channel *c*. Each particle moving around the search space in each iteration. The equation suggests the movement of each particle towards the best position that has ever been experienced (*Pbest*) and the best position of swarm so far (*Gbest*).

## IV. Result And Analysis

### A. Network Simulation

The simulation parameters used in this research to build the network topology are described in Table 2. Minimum and maximum distance between each UE and BS had to be defined. The position of each UE and femto BS is randomly deployed. Fig 2 shows the network topology in a cell site that consists of macro BS, macro UE, femto BS, and femto UE.

Both of femto BS and femto UE are desgined inside the apartment block.

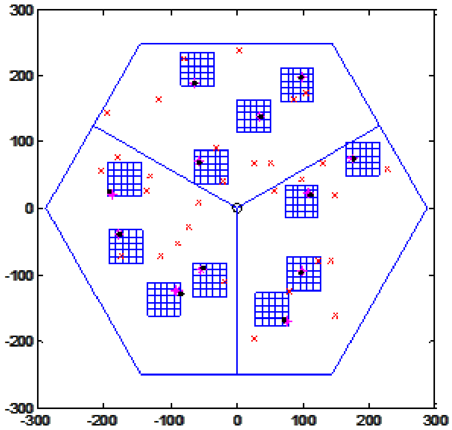

Fig 2. Network topology

TABLE 2. SYSTEM PARAMETERS AND VALUES

| No | Parameter | Value (meter) |
|---|---|---|
| 1 | Minimum distance macro user - serving macro BS | 35 |
| 2 | Maximum distance macro user - serving macro BS | 250 |
| 3 | Macro UE distance – Macro UE | 10 |
| 4 | Minimum distance Makro BS – Femto BS | 35 |
| 5 | Minimum distance Femto BS – Femto BS | 35 |
| 6 | Minimum distance Femto UE – serving Femto BS | 0.2 |
| 7 | Minimum distance of apartment blocks – Macro BS | 70 |
| 8 | Minimum distance of the centre of an apartment block – apartment block | 70 |
| 9 | Maximum distance Femto BS – centre of apartment | 5 |

## B. *Interference Effect in Heterogeneous Network*

Fig. 3 shows that variations in number of apartments, ($N$ = 2, 3, 4) do not affect the value of CDF-SINR of femtocell networks. This is because the distance between the apartment and other apartments is quite far, 70 m, thus the signal from femto BS in an apartment will not interfere the femto BS in other apartment.

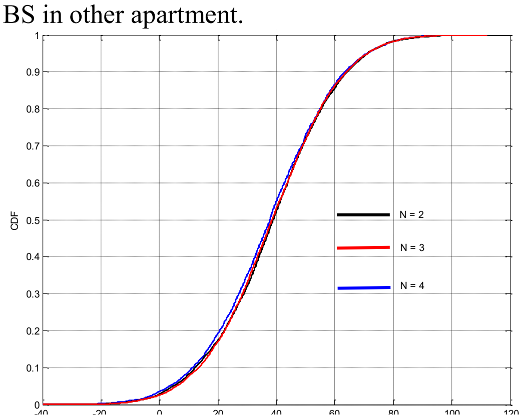


Fig 3. Number of apartment variation

Graphs of CDF-SINR of femto UE with Femto BS variations ($F$ = 2, 18, 25) in Fig. 4 show the differences. Where as the SINR value increases, the CDF value will also increase. The greater value of inteference reveals the possibility of higher SINR value.

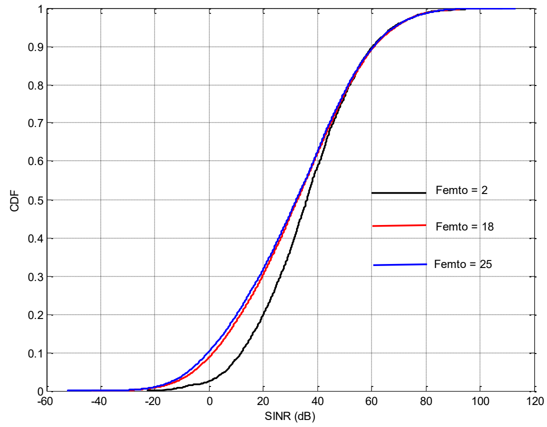


Fig 3. Number of femtocell variation

## C. *Performance Analysis with PSO*

In the application of PO algorithm, each particle represent a femto BS and the target/food represents the subset of resource block. The PSO parameters value that used in this research are described in Table 3.

TABLE 3. SYSTEM PARAMETERS AND VALUES

| Parameter | Value |
|---|---|
| Number of particles | 30 |
| $c_1$; $c_2$ | 2 ; 2 |
| Wmin; Wmax | 0,4 ; 0,9 |
| Number of iteration | 150 |

The particle movement in finding foods are able to minimize the interference which leads to improve femtocell network throughput. The best solution is updated in each iteration. Based on the simulation results, fitness values which are interference values in femtocell networks can be minimized by using the PSO algorithm. After some iteration, the convergence is achieved. The behaviour of particles in optimizing their best value is shown in convergence graph (Fig 5).

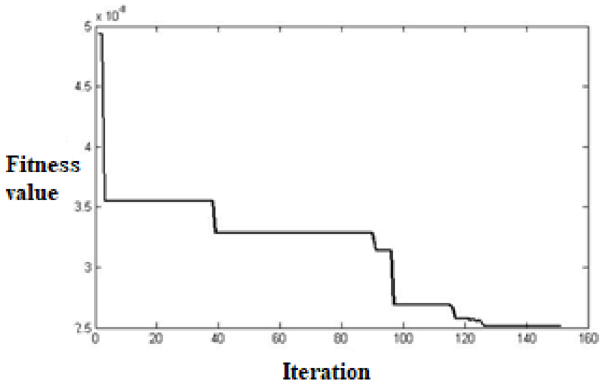


Fig 5. Fitness value in a single simulation

Fig. 5 shows at iteration 125-th, the fitness values reach its convergent value. The comparison of total interference of femto UE between random allocation and PSO algorithm in 135 times simulation is recorded in a CDF graph in Fig. 7. Generally, the total interference of each femto UE based on PSO algorithmdecreases 1,2 dB. Fig. 6 shows the comparison of total throughput between random allocation and particle swarm optimization in 30 different topologies. It

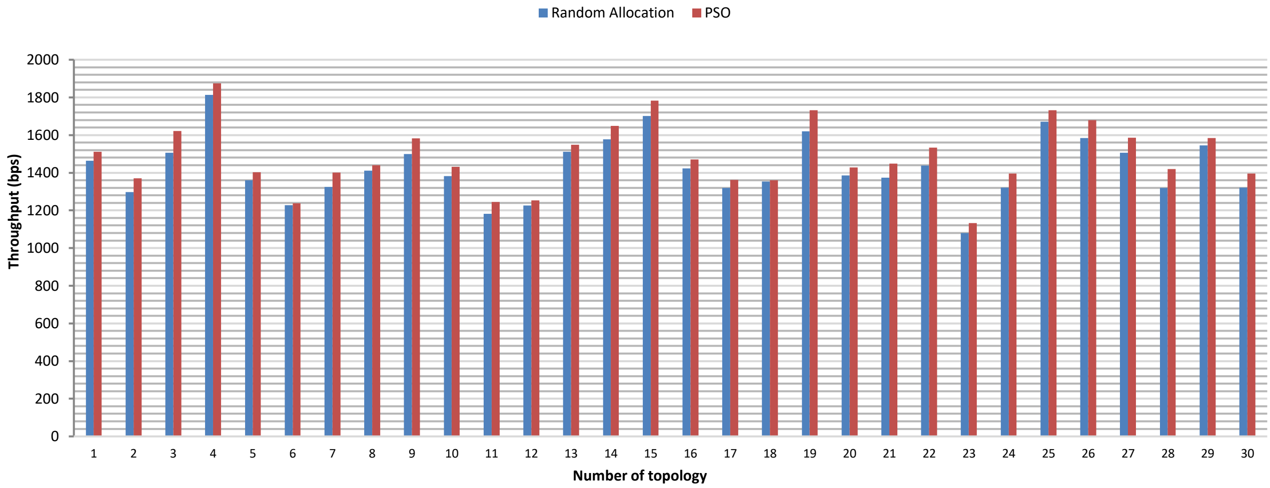


Fig. 6 Throughput with PSO vs Random Allocation in 30 number of topology

is shown that PSO algorithm works efficiently to increase the throughput value of femto UE up to 62,2 Mbps by minimizing the interference.

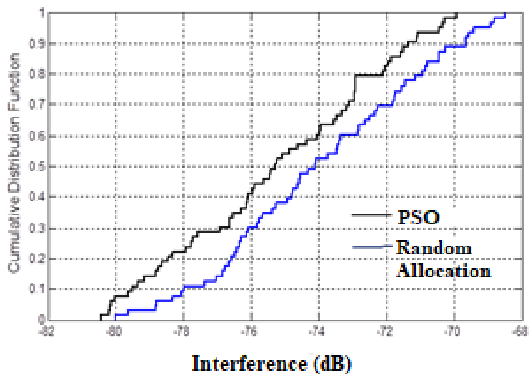


Fig 7. CDF of SINR for PSO vs. Random allocation

## V. CONCLUSION

Interference value in femto UE can be minimized using PSO algorithm. This is indicated by the CDF graph after optimization is located on the left side of the CDF graph before optimization. The throughput value can be maximized up to 62,2 Mbps. It is shown that PSO algorithm can minimize the interference effectively.

## REFERENCES


[1] 3GPP TR 36.814 V9.0.0, "Evolved Universal Terrestrial Radio Access (E-UTRA); Further advancements for E-UTRA physical layer aspects (Release 9)," 3rd Gener. Partnersh. Proj. Tech. Rep, vol. 9, no. 3, pp. 1–104, 2010.

[2] I. W. Mustika, K. Yamamoto, H. Murata, and S. Yoshida, "Potential game approach for self-organized interference management in closed access femtocell networks," 2011.

[3] F. Afroz, K. Sandrasegaran, and H. Al Kim, "Interference Management In LTe Downlink Networks," Int. J. Wirel. Mob. Networks, vol. 7, no. 1, pp. 91–106, 2015.

[4] M. . Hinchey, R. Sterritt, and C. Rouff, "Swarm and swarm intelligence," Computer (Long. Beach. Calif)., vol. 40, 2009.

[5] M. B. Pereira, F. R. Maciel, P. Cavalcanti, and T. Ferreira, "Particle Swarm Optimization for Base Station Placement," Int. Telecommun. Symp., 2014.

[6] H. Marshoud, H. Otrok, H. Barada, R. Estrada, A. Jarray, and Z. Dziong, "Resource allocation in macrocell-femtocell network using genetic algorithm," 2012 IEEE 8th Int. Conf. Wirel. Mob. Comput. Netw. Commun., pp. 474–479, Oct. 2012.

[7] H. Marshoud, H. Otrok, H. Barada, R. Estrada, and Zbigniew Dziong, "Genetic Algorithm Based Resource Allocation and Interference Mitigation for OFDMA Macrocell-Femtocells Networks," IFIP WMNC, 2013.

[8] D. Liu, H. Zhang, W. Zheng, and X. Wen, "The sub-channel allocation algorithm in femtocell networks based on ant colony optimization," IEEE, 2013.

[9] R. Estrada, H. Otrok, and Zbigniew Dziong, "Resource allocation model based on particle swarm optimization for OFDMA macro-femtocell networks," IEEE ANTS, 2013.

[10] Z. Li, S. Guo, W. Li, S. Lu, D. Chen, and V. C. M. Leung, "A particle swarm optimization algorithm for resource allocation in femtocell networks," 2012 IEEE Wirel. Commun. Netw. Conf., pp. 1212–1217, Apr. 2012

[11] X.-S. Yang, "A new metaheuristic bat-inspired algorithm," in Nature inspired cooperative strategies for optimization (NISCO 2010), Springer, 2010, pp. 65–74.